Appendix A - Design basis

Contents

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Acronyms

BOP Blow Out Preventer. 5

COG Center Of Gravity. ii, iii, 3, 16, 18–20, 28, 29

CW Counterweights. 11, 19, 20

DIR Document Information Record. 2, 21

FCM Flow Control Module. 11, 16, 18–20, 28, 29

HSE Health Safety and Environment. 25

HXT Horizontal Xmas Tree. 5

LTRT Light Tree Running Tool. 7, 15

MN Material number. 2

PPT Powerpoint presentation. 6

ROV Remotely Operated Vehicle. 9

SCM Subsea Control Module. 11, 18, 19, 28, 29

SW SolidWorks. 19

TRT Tree Running Tool. ii, iii, 1, 3–5, 7, 9, 10, 12, 14, 15, 17, 22, 24, 26, 29

VXT Vertical Xmas Tree. 5

WLL Working Load Limit. 22, 28, 29

XT Xmas Tree. ii, 3–7, 9–21, 23, 24, 28, 29

XTHT Xmas Tree Handling Tool. 1, 5, 6, 11

1 Introduction

The design basis explains and reflects the different challenges that is important to have in mind when designing the Xmas Tree Handling Tool (XTHT) and the Tree Running Tool (TRT). These challenges, standards and previous configuration of the tools will define the limitations of the designs. Safety, worst case scenarios and simple usage of tools have been in focus.

The XTHT and the TRT have a lot in common, since both are lifting tools. Therefore, one design basis are made for them both, where the more tool specific requirements are mentioned throughout the design basis.

The last part of the design basis covers an overview for each tool, with the requirements that have been concluded throughout the design basis.

It is expected that reader is familiar with the subsea technology. This is necessary to follow and comprehend the sense of the design basis. Chapter 2.1 - "Subsea" in the main report covers a basic description of the subsea techonolgy and would be appropriate for unfamiliar readers to look at before reading the design basis

2 Relevant standards, Aker Solution documents and material numbers

To ensure compliance with the requirement, this chapter list all the relevant standards and Aker Solutions documents to be used in the product development. Relevant Material number (MN)'s are also listed in the chapter.

Note: Not every document and material number are used as sources throughout the design basis. Some of those are only dimensions references or policy documents and not specified used as sources in this appendix. Those who are, are listed in the bibliography at the end of the document

2.1 Relevant standards

The design of both XTHT and TRT shall comply with the standards listed in Table 1, to ensure a development of a tool which are safe in use.

Note: For this bachelor thesis, the design would be based on Aker Solutions intern design manuals for lifting equipment or other design relevant documents made by Aker Solutions. These often refers and are based on the mentioned standards below

Document no.	Description	Revision
NORSOK R-002	Lifting equipment	Rev 2, September 2012
NORSOK R-003	Safe use of lifting equipment	Rev. 2, July 2004
DNV 2.7-3 or DNVGL-ST-E273	Lifting of portable offshore units	April 2016
ISO 13628-4	Subsea wellhead and tree equipment	15.12.2010

Table 1: Relevant standards

2.2 Aker Solutions documents

Table 2 shows a list of the Aker Solutions documents that are relevant for the design of the tools. Document Information Record (DIR) is the is a unique identity code for the specific document.

Note: Because of the confidentiality agreement signed by the students and the company, internal Aker Solutions documents cannot be attached to the report. They can only be listed and referred to

DIR	Description	Revision
10000008969	Subsea abbreviations	19.09.2016
10000013797	Design Review Global Procedure	30.05.2018
10002076797	Design manual - Lifting equipment	10.11.2015
10000888332	Design manual - Framework - Subsea trees	08.10.2015
10000103606	Interface management	01.07.2013
10000108245	Safety, Risk and Reliability	02.11.2009
10002024142	Material and fabrication requirements	23.04.2015
10002277406	Procedure for ROV access check	20.12.2013
10000233693	Calculation report - XT handling tool	18.02.2014
10002484774	Calculation report - VXT handling tool	09.12.2014
10003371348	Calculation report - LTRT	02.12.2016
10002988506	Basis of design - IVTC-RT	19.12.2016
10002077440	Basis of design - TRT - Aasta Hansen	28.02.2014
10000301877	Product data sheet - XT Handling tool	10.02.2015
10000290510	Product data sheet - Light TRT	28.11.2016
10001973398	Product data sheet - TRT	14.11.2014
10003522419	Guidelines for design of tools	20.11.2018
10002033603	Transportation & COG drawing	07.01.2015

Table 2: Relevant Aker Solutions documents

2.3 Material number

A material number or part number is a code that identifies a particular part design. If two components or assemblies have the same functionality and design, they could have the same material number. A serial number, will on the other hand, be a unique code related to the component.

The following table shows the material numbers that are relevant for the design of the tools.

Material number	Description
10298361	Ærfugl 7x5 VXT
10308693	Troll Phase 3 7x7 VXT
10188384	Aastad Hansen 7x5 HXT
10188785	Moho 5x2 VXT
10216746	Kaombo 5x2 VXT
10281631	Dvalin 7x5 HXT
10010151	KG-D6 7x2 HXT
10014224	XT Handling tool, 70t
10038167	Light TRT
10262463	IVTC RT - Internal Vertical Tree Cap Running Tool
10188386	TRT
10169376	VXT Handling tool, 70t
10188212	MVB with H4 profile - Aastad Hansen

Table 3: Material numbers

3 Product description

This chapter gives a simple and general description of both todays XTHT and TRT, as well as the H4 profile which is mentioned a lot throughout the design basis. Both tools have an interface to the 18-3/4" H4 profile which enables lifting of XT's, or similar objects with this interface.

3.1 H4 profile

The H4 profile is located at top of the XT's and is a part of the spool. Vetco Gray has the ownership and patent of this profile and is used worldwide on every Horizontal Xmas Tree (HXT) and wellhead housings, as well as some Vertical Xmas Tree (VXT)'s

It is an important interface which enables locking and sealing towards its connections, as shown at the illustration. Sealing is only necessary within subsea usage. The H4 profile comes in different sizes, measured at inner diameter, but the size which is relevant for this design is 18-3/4".

The H4 profile is designed to withstand enormous forces and loads. During completion of the well, the Blow Out Preventer (BOP) is installed at the H4 profile, which function as a barrier between the open well and the rig. Weight and height specifications for a typically BOP are 350 tonnes and 15 meters [1], which means that loads applied to the H4 profile during the lifting scenarios mentioned further down in this design basis does not need to be considered.

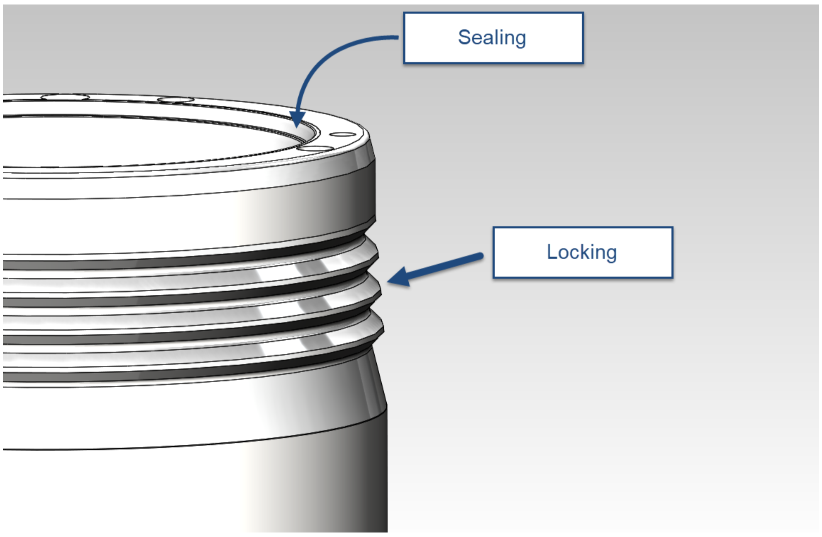


Figure 1: H4 profile with it's locking and sealing interface (Source: Aker Solutions, MN: 10281631)

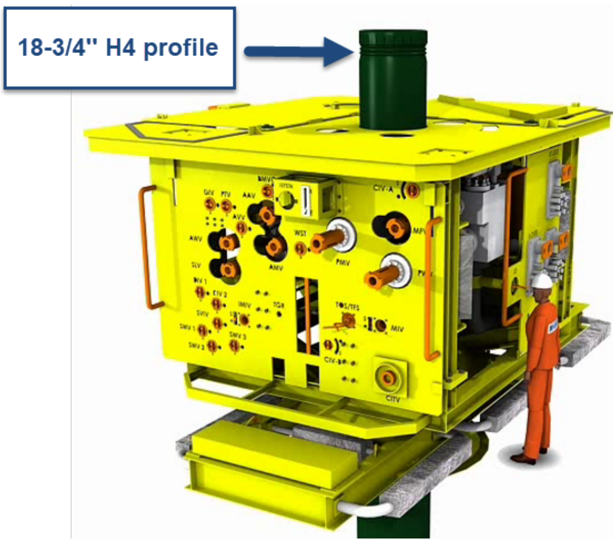


Figure 2: Figure shows were the H4 profile is located at the XT (Source: Aker Solutions, PPT)

3.2 Xmas tree handling tool

The XTHT is a tool dedicated for lifting and handling of various types of XT's, XT spools and other equipment with the same interface (18-3/4" H4 profile).

The XTHT either use locking dogs or a split lock ring to secure a safe and steady lifting connection to the H4-profile. The locking mechanism is currently engaged and locked mechanical by the operator, for example with hand tightened set screws.

The tool can be used when transported in the workshop, from dock to vessel, from vessel to rig and internal on the rig, including the drilling area. The XTHT is not suitable subsea use [2].

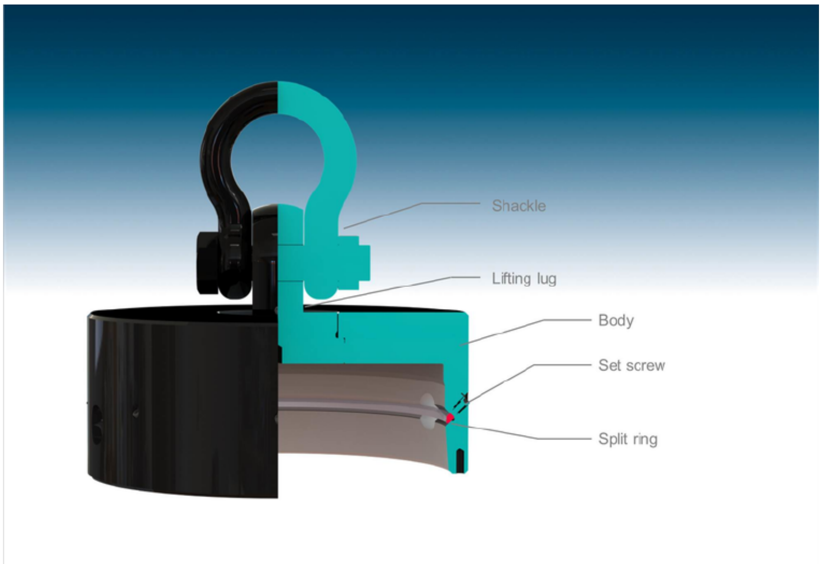


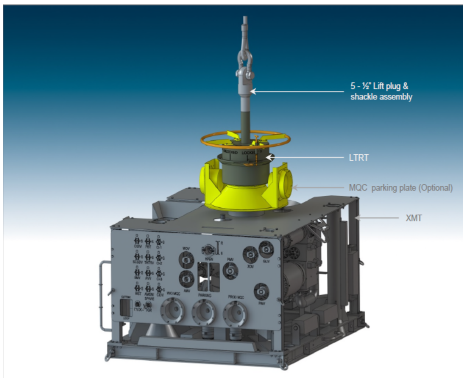
Figure 3: XTHT (Source: Aker Solutions, DIR 10000301877)

3.3 Tree running tool

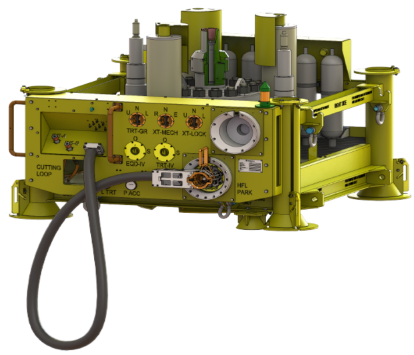
TRT is a tool used to install or retrieve the XT subsea, where the XT is either landed or retrieved from the 18-3/4" wellhead. The TRT connects to the H4 profile with locking segments.

It is many different configurations for the TRT, but the main difference is that's it either mechanical or hydraulic operated. If the TRT is mechanical operated, the ROV connect/disconnect the TRT from the XT with it's grabbing arms. This configuration is called Light Tree Running Tool (LTRT).

If it is desired to do leak and function testing of the XT valves, as well as connection testing towards the manifold during the installation, a hydraulic TRT configuration is necessary. The TRT then gets its hydraulic supply from the rig/vessel through an umbilical/cable. This section is sourced from [3]



(a) Mechanical TRT (Source: Aker Solutions, DIR 10000290510)



(b) Hydraulic TRT (Source: Aker Solutions, DIR 10001973398)

Figure 4: The two configurations of TRT

4 Selection of lifting point

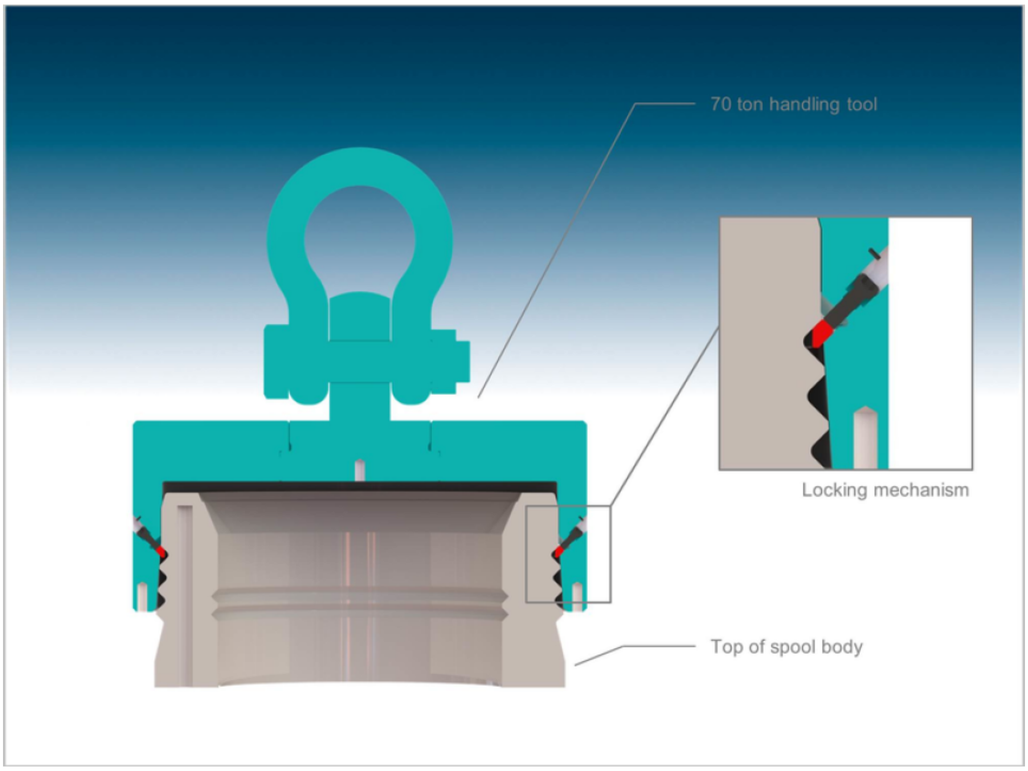


Figure 5: Todays lifting point and XTHT with split lock ring (Source: Aker Solutions, DIR 10000301877)

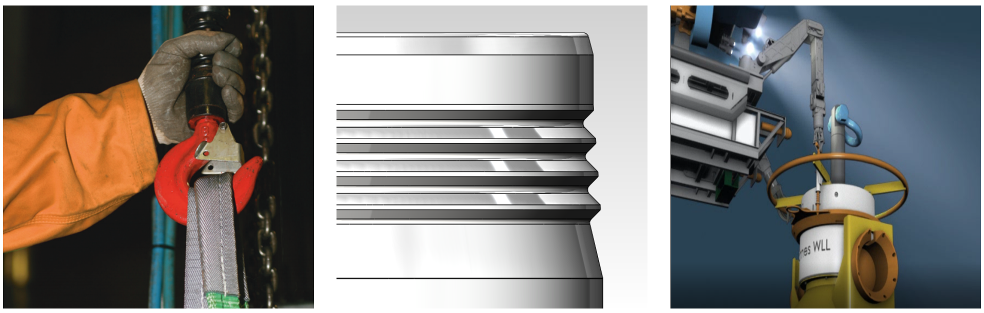
As mentioned in section 3.1, todays tools engages to the 18-3/4" H4 profile. In selection of lifting point for the new design, the following must be considered:

- If the new design requires new lifting point/points, calculations for the actual area need to be done.
- If the same lifting point (18-3/4" H4 profile) and locking mechanism is to be used, and the design of the tool causes moments or horizontal forces to the locking mechanism, then such calculations has to be covered in previous calculation reports. If this isn't covered, studies and calculations of this needs to be done. Factors of importance are moment, rotation and horizontal force. Straight lift calculations are done at previous tools.

5 Interfaces

During the design of the tool, it is important to consider the different interfaces which the tool will experience. The following are the relevant interfaces.

- **Crane hook interface**
  There will be an arrangement for the crane hook that enables lifting of the tool. Potential hooking hazards and risk of injuring people, need to be considered. The TRT could also be lifted by drillpipe.
- **Interface to XT**
  - 18-3/4"H4 profile
    As mentioned previously, this is an important interface. The tool need to be fitted to the H4-profile in a way that doesn't damage the spool. The hydraulic TRT also needs to have sealing by a VX seal, which also is own by Vetco Gray and seals towards the H4 profile.
  - Other attachment points at XT
    As mentioned previously, calculations in strength for the new area needs to be done if the design requires new attachment points. Also be aware of that the new interface should not conflict with any other tools or moving parts at the XT.
- **Tool to operator interface**
  Designing the tool should be done in a way were focus on functionality and the safety for the operators are at the highest priority.
- **ROV interface (TRT)**
  During the installation/retrieval of the XT, the Remotely Operated Vehicle (ROV) is only guaranteed access to the TRT from above or from the same side at which the ROV panel at the XT is located. This is important to take into account when designing the concept solution for the TRT, as an inconvenient ROV interface could create problems for the ROV, which in worst case could result in a misrun of the XT.



(a) Operator interface, (Source: Aker Solutions, "Just rules" PDF)
(b) H4-profile interface (Source: Aker Solutions, MN: 10281631)
(c) ROV interface (Source: Aker Solutions, printscreen of movie)

Figure 6: Interfaces

6 Lifting scenarios

A XT goes through a lot of different lifting scenarios through its life cycle. Independently of each lifting scenario, the tools need to have the possibility to be lifted both alone and with XT, in a level and steady position. This chapter list the different requirements at each scenario.

In general, the tools need to have a size that satisfies the dimensions to its surroundings. If the size of the tool is too large it might create limitations for the lift. The XT is the one component that should be the limiting factor for the lift.

Table 4 defines the different lifting scenarios and relates to Figure 7.

	Lifting scenarios	Color	Tool
1	Internal in workshop	Purple	XTHT
2	From workshop onto truck	Purple	XTHT
3	From on-shore to cargo ship	Green → Blue	XTHT
4	From cargo ship to on-shore	Blue → Green	XTHT
5	From on-shore to service-vessel	Green → Blue	XTHT
6	From service-vessel to subsea*	Blue → Yellow	TRT
7	From service-vessel to rig*	Blue → Orange	XTHT
8	From rig to subsea*	Orange → Yellow	TRT

Table 4: Lifting scenarios, colors relate to Figure 7.

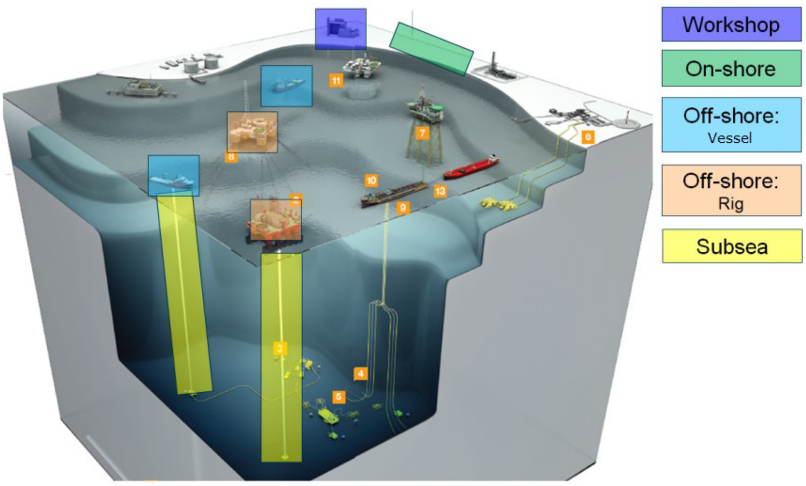


Figure 7: All the relevant lifting scenarios, related to the colors in the table (Source: Aker Solutions, DIR 10000888332)

*Installation or retrieval of the XT could either be done by the service vessel or a rig. Depends of the XT's size, cost, availability, lack of time, etc.

Note: A retrieval of a XT from the seabed, will have the same lifting scenarios and therefore same requirements, only difference is that it is done in the reversed sequence.

6.1 Lifting scenario no. 1- Internal in workshop

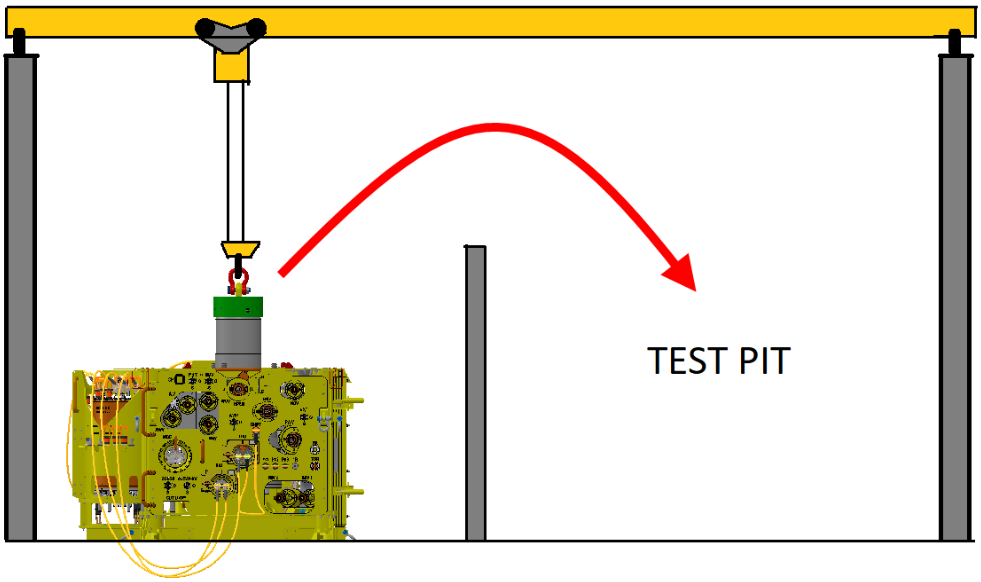


Figure 8: Lifting scenarios no.1

The XT is often moved around in the workshop due to different stations like assembly, disassembly, testing and services stations.

Typical for lifting internal in the workshops is the height limitation. There are different challenges that could occur if the XTHT gets to high, for example lifting the XT into to a test pit where the walls are high.

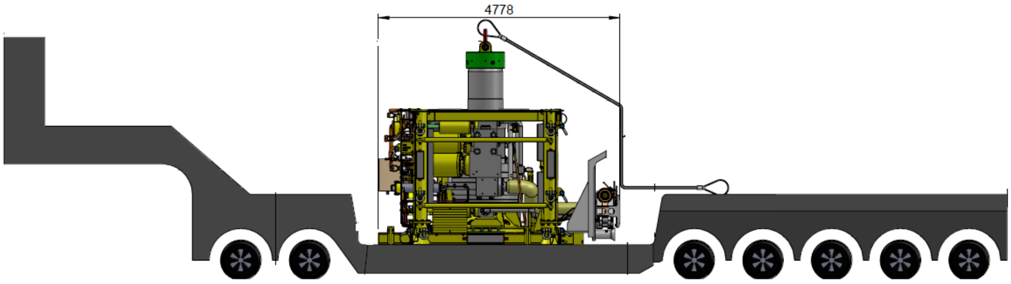
Another limitation at the workshop is weight. A fully stacked XT with Flow Control Module (FCM) and Subsea Control Module (SCM) can have an total weight up against 70 tonnes, which in many workshop will be close to the crane capacity. Todays XTHT's have weights at approximately 600-800kg [2]. This weight, along with the XT and its Counterweights (CW), makes the total lift limit. Creating a tool should have a weight goal resulting in a lighter lift. In other words:

$New\ tool\ weight < Average\ CW\ weight + Todays\ tool$ weight.

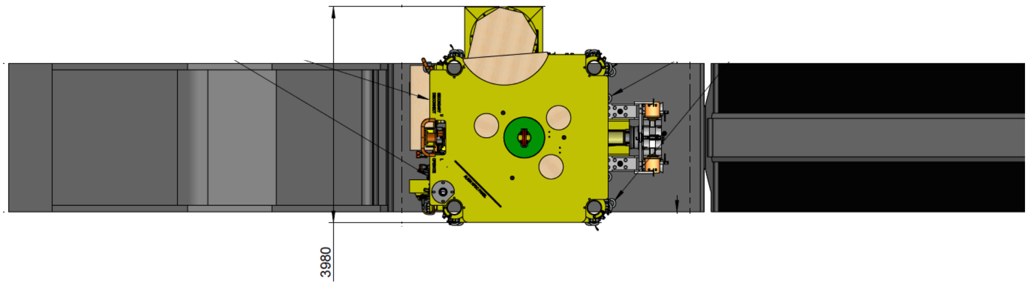
After talking to workers in the workshop and completed the cost study [4] which also shown a typical CW weight, following requirements are set for the XTHT.

- Max height: 2m
- Max weight: 5 tonnes
- Lifting capacity - 70 tonnes

6.2 Lifting scenario no. 2 - From workshop onto truck



(a) XT on truck, side view



(b) XT on truck, top view

Figure 9: Lifting scenarios no. 2 (Source: Aker Solutions, DIR 10002033603)

The XT sometimes needs to be moved by truck, as for example from finished assembly to the quay, or from workshop to another workshop. The XT is lifted onto the truck by the workshop crane, and thereby the requirements complies with the previous lifting scenario.

However will a possible road transport define some limits for the tools. According to DIR 10000888332 [5], the restriction for transportation at Norwegian roads are as follows:

- Max width 4000 mm
- Max length 5000 mm
- Max height 4500 mm

As Figure 9 show, a typical XT is close to these dimensions. Therefore, to ensure that the XTHT does not exceed these limits and reaches beyond the XT outer framework, requirements for the XTHT is as follows:

- 3500mm x 3500mm [width x length]
- Within XT's outer framework

Notes:

- *When the lifting point is selected, it is important to be aware of these requirements.*
- *The length and width limitations for the TRT can be based on previous TRT configurations, as some of these have lengths and widths greater than 3,5mx3,5m [6]. Typically they have the same dimensions as the roof, as the TRT is going to align with the guide posts*

6.3 Lifting scenario no. 3 - From on-shore to cargo ship

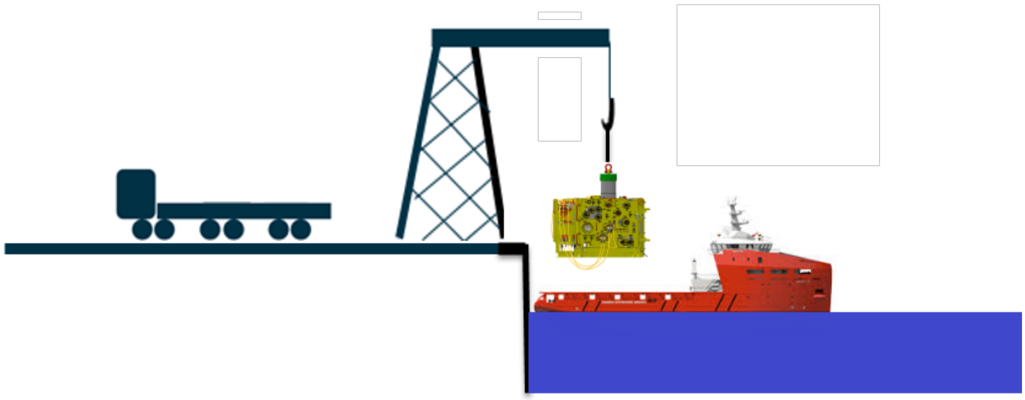


Figure 10: Lifting scenarios no. 3, 4 and 5

Note: The two next scenarios is very similar to this scenario, therefore the same requirement applies to these scenarios.

Road transportation is not always sufficient in delivery the XT to service-vessel which is going to install the XT. Therefore, shipping it by a cargo ship from one port to another would be necessary.

The XT is lifted either by the cargo ship crane or the crane at the quay. There are no relevant dimension limitations at this scenario, but the general lifting capacity of the cranes are as follows:

Lifting capacity

This depends on the quay and what is available at the site. Anyway, Aker Solutions states that there will always be cranes at the quay or the vessel to perform the lift of the XT, as this is specified in the project contract. A quay or a service vessel could typically have cranes with lifting capacities at 135 tonnes, referring to source no. [7] for quay crane and source no. [8] for vessel crane capacity.

6.4 Lifting scenario no. 4 - From cargo ship to on-shore

This scenario is the lifting situation as the cargo ship have reached the new port and is going to unload the XT. As mentioned the requirements is the same as for the previous scenario.

6.5 Lifting scenario no. 5 - From on-shore to service-vessel

This scenario is the lifting situation as the service-vessel which is going to install the XT subsea or bring the XT to the rig, loads the XT. As mentioned the requirements is the same as scenario no. 3.

6.6 Lifting scenario no. 6 - From service-vessel to subsea

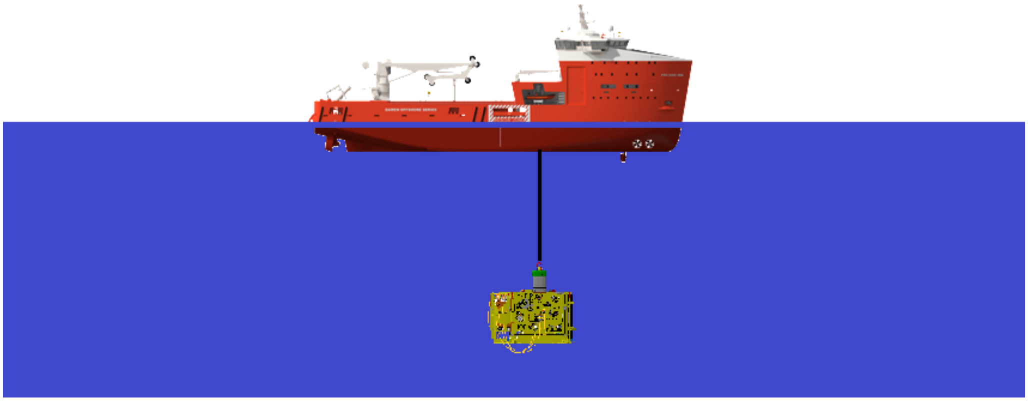


Figure 11: Lifting scenarios no.6

Installing the XT with a service vessel create some requirements for the design of the TRT. The service vessel is in general a smaller unit compared to a rig, as it has a smaller moonpool and a lower crane capacity. It is also more sensitive and affected to the motion of waves and ocean currents.

The lifting capacity for the TRT should be the same as for the XTHT, and therefore set at 70 tonnes.

Based on conversations with experienced Aker Solutions employees, moonpool dimensions is typical 4,8mx4,8m. This is larger than the road transportation restriction explained in scenario no. 2. Thereby, the width and length limitations for the TRT would be based on scenario no. 2.

Figure 12: A typical moonpool with a cursor guiding system (Source: https://www.macgregor.com)

When it comes to the moonpool crane at the service vessel, three restrictions are relevant:

1. **Height between deck and crane**
   A typical height in a moonpool at a service vessel is 10m from water level to hook.

Then the distance from top of XT to hook is typically 4m. In other words, the TRT can be 4m tall. This is data is based on the experience of Aker Solutions employees

2. **Off-center lifting**
   If the final design is an off-center solution and the moonpool crane is fixed to a specific position, the XT could collide in a already tight moonpool due the off-center lifting point. A study is done further down in the design basis to find the maximum off-center distance, with a result at 0.5m. In most moonpools, there would be enough space for such a displacement, and thereby this would not be a problem. This conclusion is based on conversations with experienced Aker Solutions employees
3. **Crane capacity**
   A typical moonpool crane capacity is 70 tonnes [8]. As explained in the product description, there are two configurations of TRT, either mechanical (LTRT) or hydraulic TRT. Thereby, the following weight requirements are settled for the two configurations:

   - Mechanical TRT - 5 tonnes
   - Hydraulic TRT - 20 tonnes

   The weight of the mechanical TRT is based on the 70 tonnes moonpool crane capacity, and is similar to the XTHT's requirement. The hydraulic TRT requirement is based on a previous TRT [6]. Because of the weight of the hydraulic TRT, a rig is often necessary.

6.7 Lifting scenario no. 7 - From service-vessel to rig

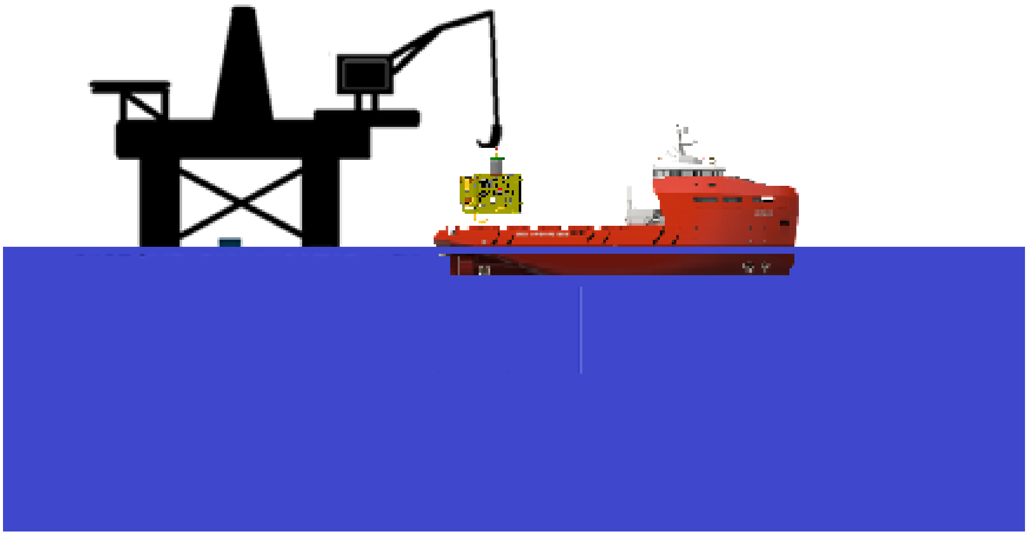


Figure 13: Lifting scenario no. 7

This lifting scenario is probably the most dangerous and restricted. The lift is done by the rig's deck crane, and due to the relative motions between the rig and the vessel, there is a large risk for collision under lift, as well as increased tension in the wire. Therefore, the requirements for wave heights and maximum allowed weight are strict. According to DIR 10000888332 [5], the maximum weight for the lift is at 50 tonnes

This creates problems for many XT's, as they exceed this limit. In such a case, the XT needs to be lifted without the FCM. This would in many cases create such a large tilt that the lift would not be possible. A universal tool that could compensate for the offset of the Center Of Gravity (COG) and stabilize the XT, would eliminate many problems regarding this issue.

Some XT exceeds 50 tonnes by a small amount. Therefore, a new XTHT which result in a lighter lift would in some cases remove the need of removing the FCM. However, the rig crane can not be decisive for the XTHT weight requirement, as many XT's are as mentioned heavier than 50 tonnes. Lifting scenario no. 1 is therefore the decisive scenario.

6.8 Lifting scenario no. 8 - From rig to subsea

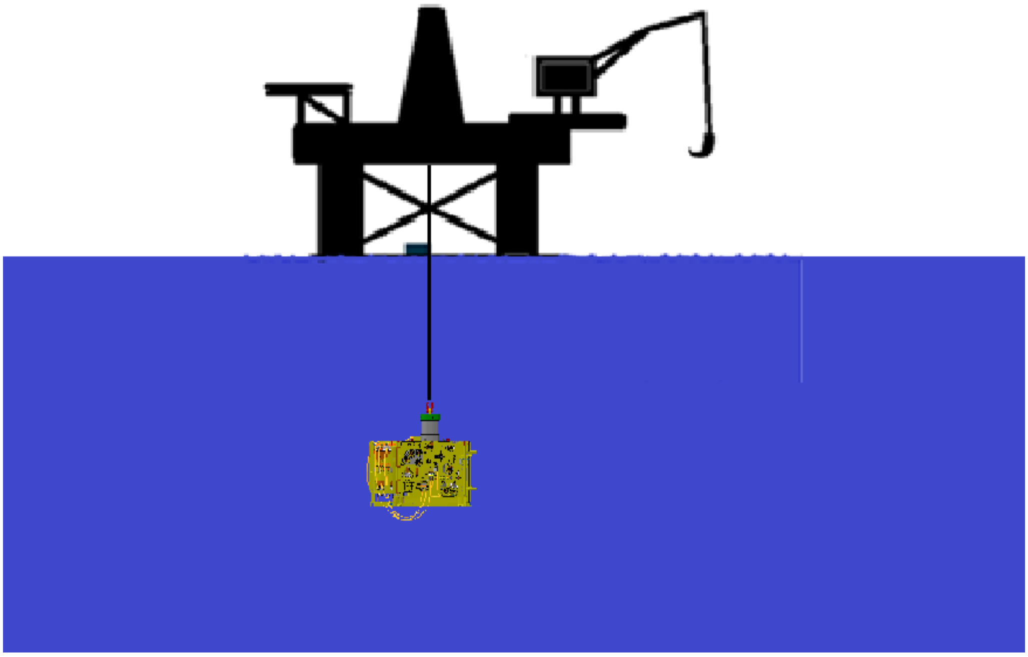


Figure 14: Lifting scenario no. 8

Installing the XT from a rig does not s set any requirements for the design of the TRT. A rig is mostly used for drilling and workover operations, which are operations that requires much larger and heavier equipment then when installing a XT using TRT. These operations are done from the rig's large moonpool and lifting equipment, as for example the top drive in the derrick which typically has a lifting capacity at 500 tonnes [9]. Therefore, lifting scenario no. 6 is therefore decisive for the TRT's requirements, as well as previous configurations of a TRT.

7 Lifting configurations

The XT is equipped with two retrievable modules, the SCM and the FCM. Since these are retrievable modules, the COG would be displaced. Hence, the tools has to be universal and lift in the following configurations:

1. Complete XT
2. Without FCM
3. Without SCM
4. XT only
5. Tool only

Note: COG and study regarding this is explained in chapter 8

Figure 15: Picture shows a complete XT lifted by the XTHT and the vessel crane, in a apparent level position (Source: https://www.bourbonoffshore.com).

8 Center Of Gravity

Center Of Gravity (COG) is a central subject regarding the design of the lifting tool. Todays design is using counterweights to compensate for the offset COG and alter the COG to be beneath the lifting point which result in a level lift.

The position of the COG various a lot from tree to tree, and even in the same project it could be a little variation. It also important to be aware of that the COG often is settled very late during the design of the XT.

Note that the CW is always mounted at the bottom of the tree to lower the COG for a more balanced lift. The height of COG will rise when counterweights are removed. A raised COG leads to increased tilt of the XT.

The maximum off-center distance from spool-center to COG that could occur is an important requirement that needs to be settled. Hence, there is done a study in SolidWorks (SW) to find the theoretical distance. The study is based on the six assigned projects, were the theoretical offset is listed in Table 5, including all five configurations. The offset is measured in millimeter and from a bird's eye-view. The next page shows the approach.

Offset in [mm]						
Client	**Project**	**with CW**	**w/o CW**	**w/o CW FCM**	**w/o CW SCM**	**w/o CW FCM SCM**
Aker BP	Ærfugl 7x5 VXT	29	123	213	133	164
Equinor	Troll Phase 3 7x7 VXT	38	193	333	193	310
	Aastad Hansen 7x5 HXT	45	0	0	0	0
Total	Moho (5x2 VXT)	57	168	120	163	50
	Kaombo (5x2 VXT)	0	0	0	0	0
DEA	Dvalin (7x5 HXT)	45	261	116	285	89
Reliance	KG-D6 (7x2 HXT)	51	218	50	258	91

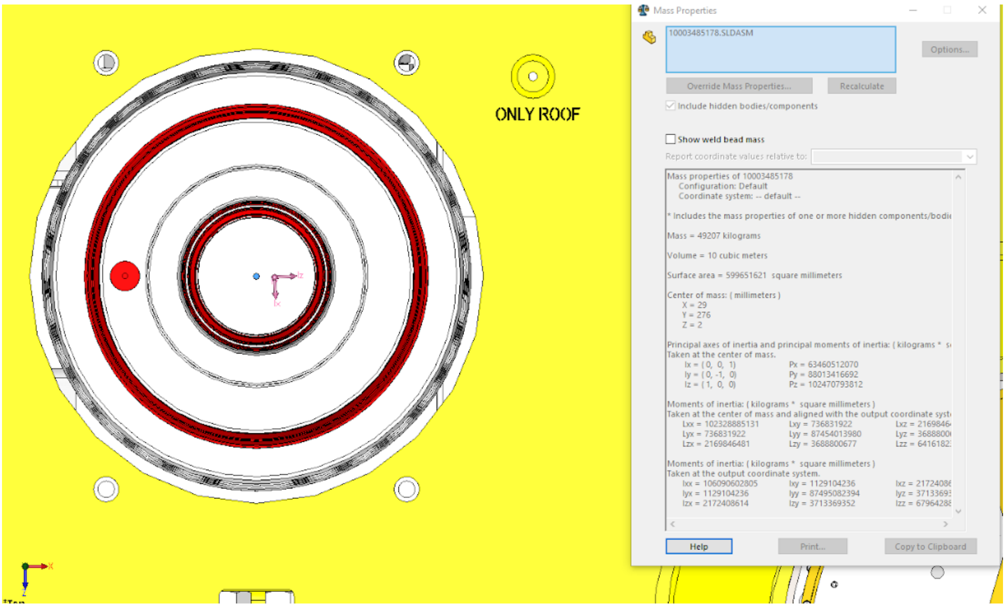
Table 5: Overview of COG offset. Maximum offset is highlighted

The greatest offset is at Troll with 333mm. Considering that other XT's could have a greater offset, a safety margin at 1.5 is used to settle the requirement of the COG's maximum offset. This result in a offset of 500mm that the new tools needs to be able to compensate for.

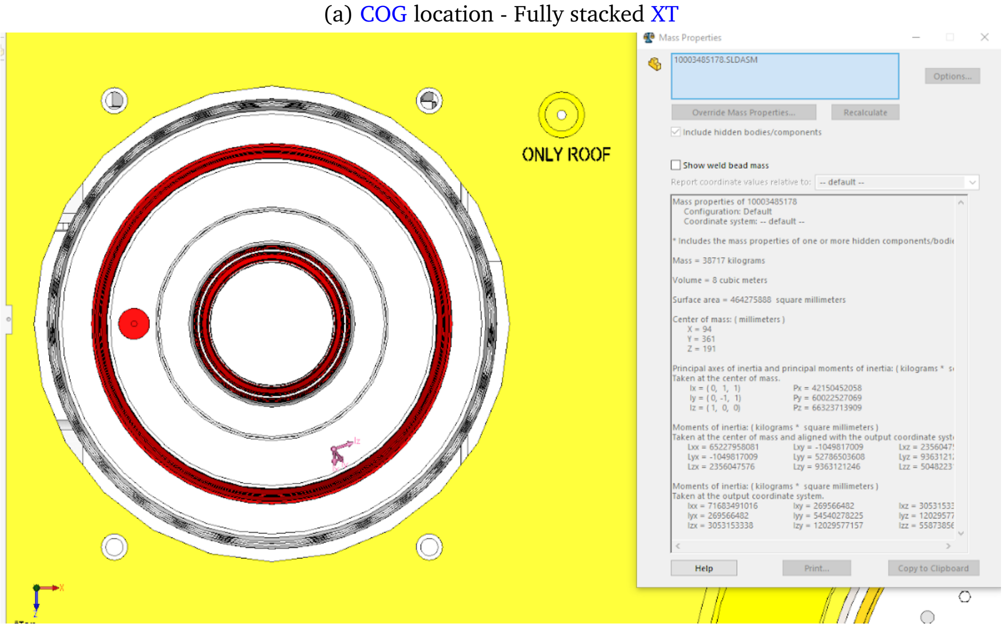
Note: Aastad Hansen and Kaombo has corrupt SW files and couldn't be opened without crashing the program. Kaombo and Moho is quite similar, so this is not a crisis

Figure 16 shows the theoretical COG displacement at the Ærfugl project. Figures 16a and 16b shows the COG position when the XT is fully stacked and when CW and FCM are removed, respectively. Note the coordinate system and the values in the right window, which is based on spool center. Pythagoras is used to find the combined offset, which the underneath calculation shows, relating to Figure 16b.

$$Offset = \sqrt{94mm^2 + 191mm^2} = 213mm$$



(a) COG location - Fully stacked XT



(b) COG location - Without CW and FCM

Figure 16: COG displacement

9 Tilt Angle

One of the most of important requirement that need to be considered is the maximum allowed tilt angle during the lift of the XT. As described in section 11 - "Failure modes", a horizontal lift is important in every scenario.

According to DIR 10002077440 [3], maximum allowed tilt is at **1.7**°. This will also be the requirement for this design basis.

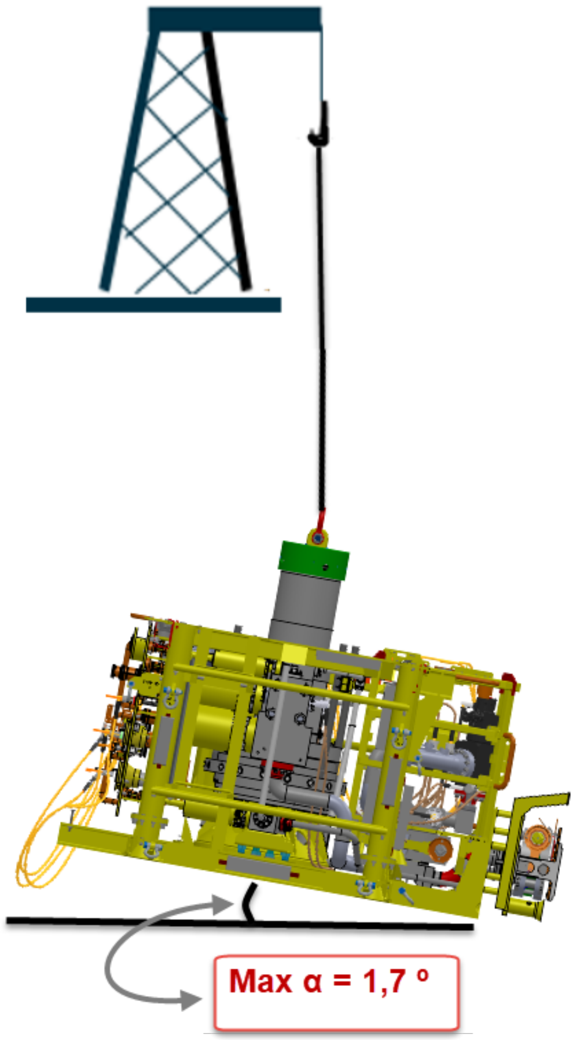


Figure 17: Figure illustrated maximum allowed tilt angle.

10 Safety factor and test factor

The safety factor is the most important and decisive factor for the design of the XTHT. This factor is multiplied with the Working Load Limit (WLL) of the tool and determines the load that will be applied during the calculations. The intention of this is to create a tool that could withstand loads many times greater than the common usage and will thereby be safe in use.

The test factor determines the load to be used during the factory acceptance test. The purpose of this test is to verify correct fabrication and functionality of the tool

Based on DIR 10002484774 [10], which is a previous calculation report for a XTHT, the requirement for the safety and test factor is listed in Table 6.

Note: DIR 10002484774 mentioned several factors, but the factors underneath is based on the worst case and highest factor.

	Structure	**Lifting point**
Safety factor	3,99	3,99
Test factor for tool	3	

Table 6: Safety and test factors

Based on these factors, the design load to be applied in FE analyses and test load to be used in workshop are as follows:

- Design load: $70t * 3.99 = 280t$
- Test load: $70t * 3 = 210t$

Note: This section only applies to the XTHT, as there are no calculations to be done at the TRT. The design load is also settled to 280 tonnes instead of 279,3 tonnes.

Note: The test factor isn't relevant for this thesis, but needs to be covered for further work and a possible implementation

11 Failure modes

Safety is vital and very central when it comes to lifting and are the first priority. To increase safety and lower the risk of failure, is it important to imagine the possible glitches that could occur and take them into account during the product development.

Because of this importance, this section reflects the general failure modes that possibly can occur to the tool. This is basically an evaluation of the whole lifting sequence of the XT, considering which important precautions that needs to be followed and possible consequences if the precautions isn't abided.

Common for all the following lifts, is a secured and safe lifting connection. Dealing with such heavy equipment could cause disaster for both people and equipment if the connections fails. A safe connection should be top priority when designing the tool.

Following are the failure modes that is important to have in mind when designing the tool. The failure modes covers the whole lifting sequence for a typical lift of a XT. In all aspects of all lifts it is important to lift horizontally, where the consequences if not are listed below

1. Attach and lifting the tool
   - Precautions
     a Horizontal lifting of the tool
     b The tool needs to have an easy way attaching the crane hook to the tool. The design should allow the shackle to be pre-attached and supported, in this way workers don't have to be in direct contact with the crane hook when mounting.
   - Consequence
     a If not lifted horizontally it may be a problem installing the tool to the XT in the following operation.
     b If attaching the crane hook to the tool provide problems, the operators could get injured, for example crushing of fingers. A complicated and disorderly arrangement could also result in frustration and stress among the workers.
2. Mounting the tool to XT
   - Precautions
     a Horizontal lifting of the tool
     b The locking mechanism need to be easy to use and it needs to have a clear indicator to verify locked position.
   - Consequence
     a If not lifted horizontal, there could be difficulties of entering the lifting point, as well as this could damage the tool or the interface.
     b If the tool is disorderly mounted it might slip as the lift start or during the lift, which consequently could injure or in worst case cause death to people close

by. The H4 profile, the tool and the XT in general could also be damaged.

3. Lifting XT
    - Precautions
        a Horizontal lift XTHT
        b Horizontal lift TRT
        c If the solution requires off-center lifting, precautions to prevent the tool from rotating at the spool needs to be done.
    - Consequence
        a If the XT isn't lifted horizontally it could be hard to land at test stand or similar onshore equipment.
        b This is extremely important when lifting offshore during installation/retrieval of the XT, to avoid damaging the wellhead and to ensure proper attaching/detaching.
        c If the tool start rotating at the spool while lifting, the rotating motion would escalate and the huge mass of the XT could crush into people or the surroundings. This could result in death or large damage to the equipment.
4. Releasing of tool from XT
    - Precautions
        a Horizontal lifting of the tool
        b When releasing it is important to completely release the locking mechanism. Indicators should verify the unlocked position.
    - Consequence
        a If the tool is lifted of with a tilt it may result in jamming at the H4-profile and damage to the interface.
        b If the releasing mechanism is not completely open, the tool may still be partly attached to the XT. There would then be a risk of the connection to slip and damage both people and equipment.
5. Parking tool and detaching the hook
    - Precautions
        a Horizontal lifting of the tool
        b As for the attaching, it is important to have an easy way to detach the crane hook from the tool. Shackle should be supported to ease the operation of detaching the hook.
    - Consequence
        a Difficulties lowering and parking the tool, may result in damage to people or equipment.
        b Same consequences as for the attaching, possible injury and frustration among the operators.

Aker Solutions lifting rules

In addition to the failure modes reflected above, the internal Aker Solutions lifting policy is valuable to have in mind during the product development. To prevent injury and harm, Aker Solutions have made some specific rules called "Just rules", which is a part of a their Health Safety and Environment (HSE) culture. These the following rules reflects their lifting policy (Sourced from Aker Solutions internal intranet)

1. The lift is properly planned and documented with all risks assessed and controlled. This shall include the:
   - Potential for falling objects and extent of the drop zone, considering that falling objects can be deflected
   - Method of communication between the lifting team
   - Safe positioning of personnel
   - Load path, snagging and obstruction hazards
   - Suitability of equipment, safe working load, centre of gravity and rigging arrangement
   - Forces generated when using mobile lifting equipment
   - Effect of weather conditions on the load
2. Equipment is certified for use and is subjected to a visual inspection before and after use
3. All safety devices are in place and are functioning correctly
4. The lifting team have checked the complete lift route
5. A banksman / flagman leads the operation
6. All personnel are kept clear of the identified drop zone by suitable means including barriers, tag-lines, warning signs, public address announcements and sentries
7. Other options have been ruled out before basket transfer or winch man-riding for the lifting of persons can take place. Such operations shall only be carried out using certified equipment, under an approved procedure and risk assessment

12 Materials

The main material of the tools needs to be defined in the design basis. The main material for the tools are set to be the same as for todays tools, which are shown in Table 7. If its beneficial or necessary to some components, other materials may be selected. Components that not experience or generate any loads, such material could be of light materials, as for example polyethylene. Further material properties is covered in appendix D - "Calculation report"

	Today's tool mat.no.	**Main material**
XTHT	10169376	Alloy steel - AISI 8630 MOD 80ksi
TRT	10188386	Alloy steel - AISI 8630 MOD 80ksi

Table 7: Main material for XTHT and TRT

13 Overview and product specific requirements

This final section sums up and list all the requirements that have been concluded throughout the design basis, with one overview for each tool.

XT lifting and handling tool

Parameter	Value
Height	2m
Length/width	3.5m x 3.5m Within XT's outer framework
Maximum tool weight	5t
Working Load Limit (WLL)	70t
Maximum distance between spool center and COG, bird's-eye view.	0.5m
Maximum tilt angle	1.7°
Safety factor / Design load	3.99 / 280t
Test factor for tool / Test load	3 / 210t
Design life	25 years and maintainable
Temperature range	-18°C to 50°C
Main material	Alloy steel - AISI 8630 MOD 80ksi
Indicators	Lock position Unlock posistion Correct positioning of tool
Lifting point	18-3/4" H4 profile Other arrangement at XT
Lifting configurations	Complete XT Without FCM Without SCM XT only Tool only
Important precautions	Horizontal lifting Rotation (off-center solution) Easy and safe way of: - Locking - Unlocking - Attach hook - Detach hook
Important interfaces	Hook XT Operator

Table 8: Overview of requirements for the XTHT

Tree Running tool	
Parameter	**Value**
Height	4m
Length/width	3.5m x 3.5m (NB: See note in lifting scenario no.2) Within XT's outer framework
Maximum tool weight	Mechanical TRT - 5t Hydraulic TRT - 20t
Working Load Limit (WLL)	70t
Maximum distance between spool center hub and COG, bird's-eye view	0.5m
Maximum tilt angle	1.7°
Safety factor / Design load	3.99 / 280t
Test factor / Test load	3 / 210t
Design water depth rating	2 000m
Hydraulic operating pressure	15 000 PSI
Design pressure	5 000 PSI
Design life	25 years and maintainable
Temperature range	-18°C to 121°C
Main material	Alloy steel - AISI 8630 MOD 80ksi
Indicators	Lock position Unlock posistion Correct positioning of tool
Lifting point	18-3/4" H4 profile Other arrangement at XT
Lifting configurations	Complete XT Without FCM Without SCM XT only Tool only
Important precautions	Horizontal lifting Rotation (off-center solution) Easy and safe way of: - Locking - Unlocking - Attach hook - Detach hook
Important interfaces	Hook XT Operator ROV

Table 9: Overview of requirements for the TRT

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